XIII. *The ſuppoſed Effect of boiling upon Water, in diſpoſing it to freeze more readily, aſcertained by Experiments. By* Joſeph Black, *M. D. Profeſſor of Chemiſtry at* Edinburgh, *in a Letter to Sir* John Pringle, *Bart. P. R. S.*

TO SIR JOHN PRINGLE, BART. P. R. S.

DEAR SIR, Edinburgh, Feb. 11, 1775.

Redde, Feb. 23, 1775.

WE had lately one day of a calm and clear froſt; and I immediately ſeized the opportunity, which I miſſed before, to make ſome experiments relative to the freezing of boiled water, in compariſon with that of water not boiled. I ordered ſome water to be boiled in the tea kettle four hours. I then filled with it a Florentine flaſk, and immediately applyed ſnow to the flaſk until I cooled it to 48° of FAHRENHEIT, the temperature of ſome unboiled water which ſtood in my ſtudy in a bottle; then putting four ounces of boiled, and four of the unboiled water, ſeparately, into two equal tea cups, I expoſed them on the outſide of a north window, where a thermometer pointed to 29°. The conſequence was, that ice appeared firſt upon the boiled water; and this, in ſeveral repetitions of the experiment, with the ſame boiled water, ſome of which

which were made nine hours after it was poured out of the tea kettle. The length of time which intervened between the firſt appearance of ice upon the two waters was different in the different experiments. One cauſe of this variety was plainly a variation of the temperature of the air, which became colder in the afternoon, and made the thermometer deſcend gradually to 25°. Another cauſe was the diſturbance of the water; when the unboiled water was diſturbed now and then by ſtirring it gently with a quill tooth-pick, the ice was formed upon it as ſoon, or very nearly as ſoon, as upon the other; and from what I ſaw, I have reaſon to think, that were it to be ſtirred inceſſantly, provided at the ſame time the experiment were made with quantities of water, not much larger or deeper than theſe, it would begin to freeze full as ſoon. In one of theſe trials, having inſpected my tea cups when they had been an hour expoſed, and finding ice upon the boiled water, and none upon the other, I gently ſtirred the unboiled water with my tooth-pick, and ſaw immediately, under my eye, fine feathers of ice formed on its ſurface, which quickly encreaſed in ſize and number, until there was as much ice in this cup as in the other, and all of it formed in one minute of time, or two at moſt. And in the reſt of the trials, though the congelation began in general later in the unboiled water than in the other; when it did begin in the former, the ice quickly encreaſed ſo as, in a very ſhort time, to equal, or nearly equal in quantity, that which had been formed more gradually in the boiled water. The opinion,

therefore, which I have formed from what I have hitherto feen is, that the boiled and common water differ from one another in this refpect; that whereas the common water, when expofed in a ftate of tranquillity to air that is a few degrees colder than the freezing point, may eafily be cooled to the degree of fuch air, and ftill continue perfectly fluid, provided it ftill remain undifturbed: the boiled water, on the contrary, cannot be preferved fluid in thefe circumftances; but when cooled down to the freezing point, if we attempt to make it in the leaft colder, a part of it is immediately changed into ice; after which, by the continued action of the cold air upon it, more ice is formed in it every moment, until the whole of it be gradually congealed before it can become as cold as the air that furrounds it. From this difcovery it is eafy to underftand, why they find it neceffary to boil the water in India, in order to obtain ice. The utmoft intenfity of the cold which they can obtain by all the means they employ, is probably not greater than 31° or 30° of FAHRENHEIT's thermometer. Common water, left undifturbed, will eafily defcend to this degree without freezing; and, if they have not the means of making it colder, may continue fluid for any time, provided it be not difturbed: the refrigerating caufes of that part of the world when they have done fo much, have done their utmoft, and can act no further upon the water. But this cannot happen to the boiled water; when the refrigerating caufes have cooled it to 32°, the next effect they produce, is to occafion in it the beginning of congelation, while the

the water is afterwards gradually aſſuming the form of ice, we know, by experience, that the temperature of it muſt remain at 32°; it cannot be made colder, ſo long as any conſiderable part of it remains unfrozen[(a)]. The refrigerating cauſes continue, therefore, to have power over it, and to act upon it, and will gradually change the whole into ice, if their action be continued ſufficiently long.

The next object of inveſtigation may be the cauſe of this difference between the boiled and the common water. In conſidering this point, the following idea was ſuggeſted. As we know from experience, that by diſturbing common water, we haſten the beginning of its congelation, or render it incapable of being cooled below 32°, without being congealed; may not the only difference between it and boiling water, when they are expoſed together to a calm froſty air, conſiſt in this circumſtance: that the boiled water is neceſſarily ſubjected to the action of a diſturbing cauſe, during the whole time of its expoſure, which the other is not? One effect of boiling water long, is to expell the air which it naturally contains; as ſoon as it cools, it begins to attract and abſorb air again, until it hath recovered its former quantity; but this probably requires a conſiderable time. During the whole of this time, the air entering into it muſt occaſion an agitation or diſturbance in the water, which, though not ſenſible to the eye, may be very effectual in

(a) Common water, when cooled in a ſtate of tranquillity to ſeveral degrees below the freeing point, will ſuddenly riſe up to it again, if diſturbed in ſuch a manner as to occaſion in it a beginning of congelation.

preventing

preventing it to become, in the leaſt, colder than the freezing point, without beginning to freeze, in conſequence of which its congelation muſt begin immediately after it is cooled to that point. When I reflect upon this idea, I remember a fact which appears to me to ſupport it ſtrongly. FAHRENHEIT was the firſt perſon who diſcovered that water, when preſerved in tranquillity, may be cooled ſome degrees below the freezing point without freezing. He made the diſcovery while he was endeavouring to obtain ice from water that had been purged of its air: with this intention he had put ſome water into little glaſs globes, and having purged it of air, by boiling and the air-pump, he ſuddenly ſealed up the globes, and then expoſed them to the froſty air. He was ſurprized to find the water remain unfrozen much longer than he expected, when at laſt he opened ſome of his globes, in order to apply a thermometer to the water, or otherwiſe examine what ſtate it was in. The immediate conſequence of the admiſſion of the air was a ſudden congelation which happened in the water; and in the reſt of his globes, a ſimilar production of ice was occaſioned by ſhaking them. The inference that may be drawn from theſe experiments of FAHRENHEIT's is ſufficiently obvious; it appears to me to remove all doubt with regard to the above ſuppoſition. Before theſe experiments of FAHRENHEIT occurred to my memory, I had planned a few, ſuggeſted by the above ſuppoſition, that might have led to the ſame concluſion; but the ſhort duration of the froſt, for one day only, did not give me time to put them in execution.

XIV. EXPE-